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ABSTRACT

While majority of the airlines are struggling to implement macro human factors principles in their maintenance activities, at least eleven corporate aviation departments (CADs) in the country are showing signs of success. The implementation philosophy of these CADs differs from others, and from the airlines in one fundamental aspect: it enforces a behavior change rather than an attitude change among the CAD employees. Consequently, they strive to achieve an employee behavior which is consistent within and across their flight operations, maintenance, and management functions.

Ethnographic research was conducted at one of the eleven eligible sites to develop a theoretical model which is representative of the structure, the strategy, and the processes used by these aviation departments to implement macro human factors principles in aviation maintenance. This model was then tested at three other CADs that have a implemented similar approach.

INTRODUCTION

This paper presents the results of field observations and interviews of aircraft mechanics, cleaners, pilots, and managers at a corporate aviation department (hereafter referred to as the aviation department). The goal of this study was to characterize how human factors principles were applied to the aviation operations at the aviation department through direct observations and informal interviews of both maintenance and flight personnel.

Instead of using the traditional Crew Resource Management (CRM) training programs available in the market, the aviation department under study decided to use an alternative approach to risk management. The <u>strategy</u> addresses risk management by focusing on team decision making. It provides the pilots and the technicians with a standard decision making process along with the times that it shall be used to effect better communication, workload management, situational awareness, etc. The <u>structure</u> is the required briefings among flight crews, among maintenance, and between the maintenance and the flight crews. The <u>process</u> is the “concept alignment process” (CAP) as a way of ensuring that all parties are acting on the same concept. If not, it provides a way of resolving ambiguous and/or conflicting viewpoints among the communicating parties in various briefings. The aviation department acquired the QuantumPro management system from Robert & Skip Mudge of CMR, Inc. (the company’s use of the term “CRM” predates the industry’s term “CRM”). After the indoctrination of this human factors technique with the Department’s flight crews, it was applied in a streamlined format to the maintenance function. In this application, the technique is used for preflight pilot briefings, post-flight pilot debriefings, and parallel briefings between the flight crew and maintenance personnel.

The basis of the concept alignment process is a simple communication protocol which desensitizes rank and provides means for all the individuals to share information. At the heart of this protocol is the *concept*. A *concept* is defined as an idea, remark, or an observation which is stated by one person and is either affirmed or challenged by the co-worker. If a difference between the points of view is stated, it is the team’s responsibility to seek validation for that *concept* from an independent third source. If one *concept* can be validated and one cannot, the validated concept shall become the working concept. If both can be validated, the choice of which becomes the working concept is up to the most senior technician. If neither concept can be validated, the most conservative of the two is chosen. Once a working concept is agreed upon, it shall be further scrutinized using a predefined judgement process. Often in this process, the mechanics, management and flight crew go beyond this point to research the cause of the discrepancy in the *concepts* and recommend appropriate changes. Changes have been made in operating policies and procedures, maintenance manuals, and other documentation as a direct result of this process. The pilots have been using this process for four years and the mechanics have employed it for just over a year.

THE CONCEPT ALIGNMENT PROCESS (CAP)

The human factors training provided by most of the vendors and airlines increases the awareness about safety issues. According to the aviation department, the concept alignment process (CAP) provides a measurable process to effect implementation of human factors. The Department's flight department was trained by CMR, Inc. Within the maintenance group, this program has been customized and named Error Reduction and Decision Making Process. The CAP, as illustrated in figure 1, is at the hub of the Department's human factors model. In this model, communication is the spoke(s) and each of the elements (from Transport Canada's dirty dozen human factors) are connected on the periphery. This model is shared by pilots and mechanics; they accept that if the CAP is adhered to, the human factors such as teamwork, norms, complacency, etc. could be addressed.

During almost 23 hours of observations conducted over one week, 24 briefings/debriefings and 8 special meetings were observed. Additionally, the issues that emerged during these observations were tracked in the following two weeks.

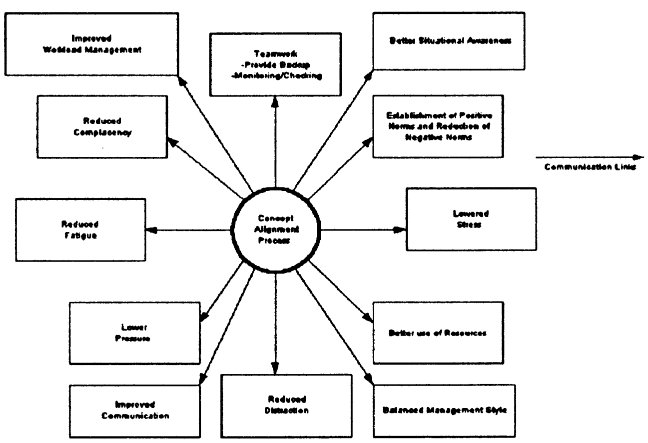

Figure 1: Concept alignment at the hub of the human factors

Through these observations, it was clear that both mechanics and pilots had a good understanding of the CAP and most of them followed the specified path. It was also evident that there was a variation in the level of detail to which an individual followed the process. An event, for example hydraulic pressure reading of less than 2900psi after the first engine start on one of the Astra jets, was a significant event for some pilots but not for all. The event's significance would have been different to different pilots because (a) if the pilots reported this event, the mechanics and the management would have to ground the aircraft and/or (b) an understanding, based on their interpretation of the language in the Aircraft Flight Manual, that the reading was normal. Also, there was a sentiment among some mechanics that the pump could be easily adjusted to have it deliver higher pressure. However, because there was no approved procedure in the aircraft maintenance manual to adjust the pressure, the chief of maintenance did not authorize pump adjustment.

On comparing the field observations with the concept alignment process expected to be followed, it is inferred that although some individuals may not drive the process to its fullest extent, the key individuals in the Department, including the management, support CAP and expect it to be adhered to. That is to say that perhaps the attitude of the "less-compliant" individuals may not have changed much since the implementation of the concept alignment process; however, their behavior has changed. Therefore, it is plausible that if the attitude and the behavior of the key individuals in an organization are aligned, the rest of the individuals may be coerced into changing behavior. The "less-compliant" individuals are perhaps a bit more skeptical about the process than the others and need some additional concrete examples to illustrate that the concept alignment process works.

The CAP is different from most of the Human Factors type training being conducted in the maintenance area because it focuses on a behavioral change rather than an attitudinal change. The organization need not change everyone's attitude before expecting a change in their behavior. The CAP forces all employees to change their behavior and follow a prearranged process. Therefore, it does not suffer from the limitations of the conventional Human Factors type training in maintenance (see Taylor, Robertson, Peck, & Stelly, 1993; Taylor, 1994, 1995, 1996 & 1997; and Taylor, Robertson, & Choi, 1997).

Figure 2 illustrates the decision making process typically followed by the maintenance personnel to resolve conflicts and align concepts. A striking correlation could be made between this process and the Reason's model discussed by Leslie (1996). In his discussion about the Reason model (see Figure 3), Leslie presents the following argument:

> "...he (Reason) identifies key elements in the system that generate accidents, and notes that while feedback loops 1 and 2, between accidents and incidents or unsafe acts and fallible decisions that occur earlier in the system sequence, are usually available and sometimes effective, loops 3 and 4, between psychological precursors of unsafe acts and line management deficiencies and those fallible earlier decisions are not generally used. A feedback loop is formally identical to a three-term contingency, and Reason is saying that while some contingencies are effective, other important ones are not implemented and thus do not change the behaviour of the operators of the complex system."

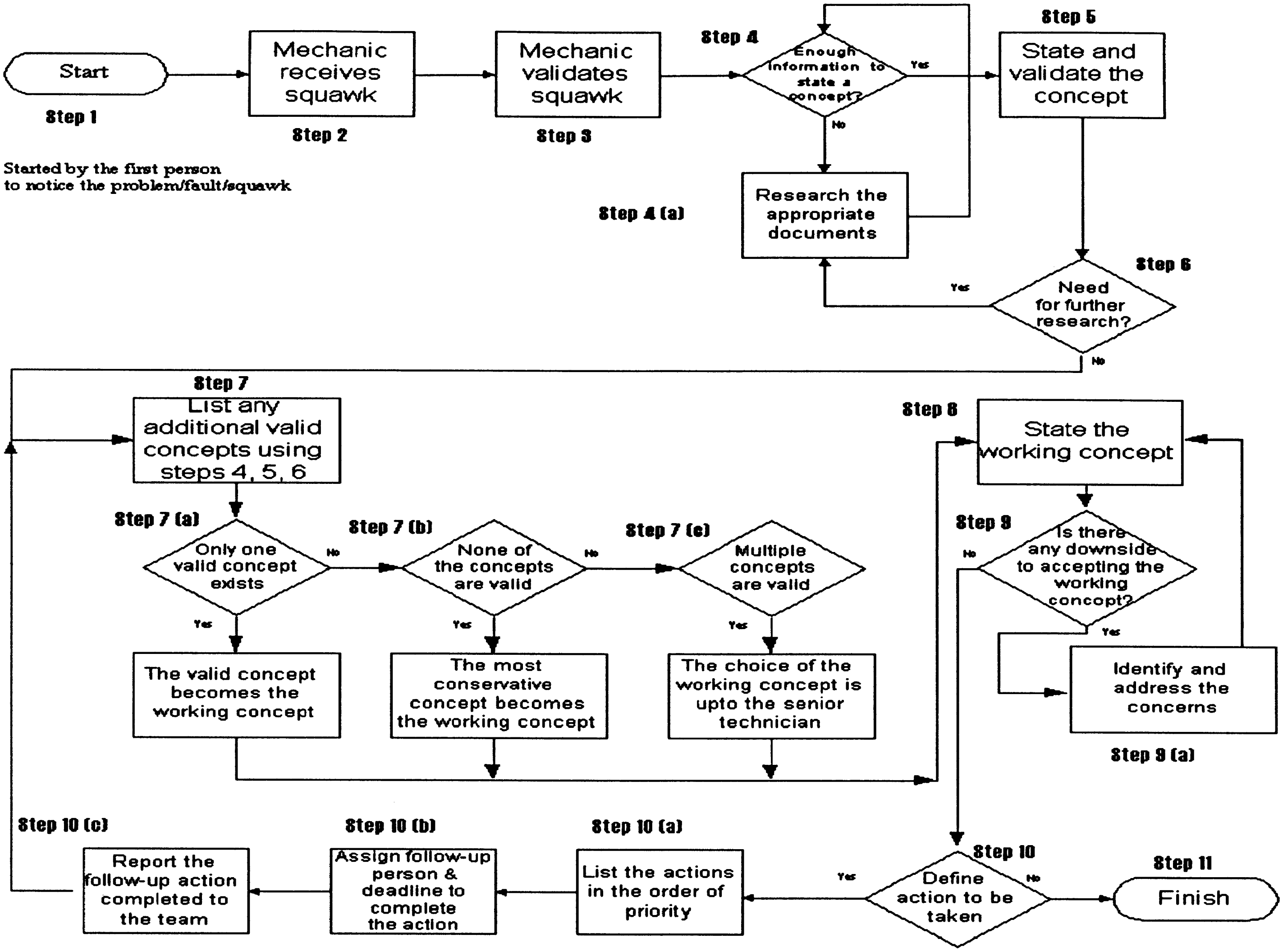

Figure 2: Decision making with the use of Concept Alignment Process

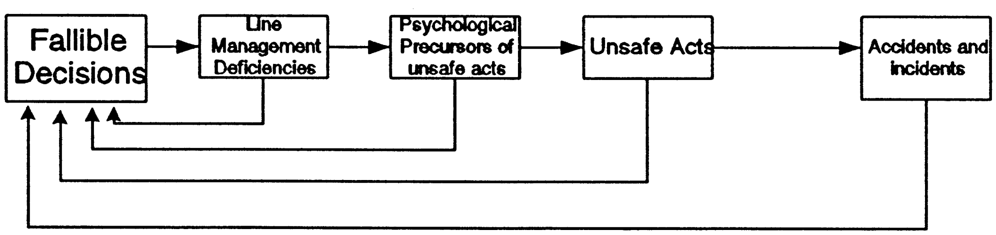

Figure 3: Reason's model

As presented in Figure 2, the steps 10 (a), (b), and (c) serve as "loops 3 and 4" per the Reason's model. It is essential to note that CAP provides the process required to operate those loops. In so doing, it also acts as an effective tool which proactively identifies and addresses risk factors on a regular basis.

In the case of the aviation department under study, the process is used as an integral part of the organization's operation. It serves as the "organizational engine" through which the management routinely welcomes innovative ideas, holds everyone accountable, develops a sense of organizational attachment, and discards bad norms (see Patankar & Taylor, 1998).

CASE STUDIES

Three case studies are presented to illustrate how the aviation department personnel have used the concept alignment process. The first two cases address maintenance related issues and the third case presents a flight operations issue.

CASE 1: LOW HYDRAULIC SYSTEM PRESSURE ON A ASTRA SPX JET – The flight crew of a routine flight verbally reported to a mechanic that the hydraulic system pressure was low after engine starts. He wrote the squawk in the aircraft logbook as, "Hydraulic system pressure reads 2800 psi after engine starts." In a maintenance team meeting that followed between the liaison mechanic, two other mechanics and the chief of maintenance, it was noted that the same discrepancy had been reported on April 16, 1998. At that time, one of the mechanics had swapped the indicator, tested the indicator, swapped the transmitter wiring, etc. but was not able to duplicate the problem. He made a note of the verbal squawk and the maintenance actions he had taken while attempting to diagnose the fault. Another mechanic reminded the team about the direct reading pressure test conducted in April which indicated 3000 psi at the pump but for some unknown reason indicated a drop of at least 100 psi at the indicator. A follow-up brief with the flight crew clarified the squawk: the hydraulic pressure was noted at 2800 psi after the first engine start and 2900 psi after the second engine start.

To further investigate the matter, one of the mechanics researched the Aircraft Flight Manual (AFM) and discovered that the manufacturer called for a minimum of 2900 psi after the first engine start. If the pressure read less than that, the aircraft did not meet dispatch criterion. Upon referring back to the squawk, the mechanic questioned as to why they were not informed about this problem prior to the departure from Corvallis. He requested a meeting with the chief pilot, the line pilot in question, and the chief of maintenance. In a discussion that followed, the line pilot stated that he had observed 2900 psi after the first engine start (number 2 engine) and the pressure had dropped to 2800 psi after the second engine start. Because the check list did not state the minimum pressure requirement with both engines running, he operated the aircraft. Furthermore, it was also discovered that the AFM did not specify as to after which engine is started, the pressure should be 2900 psi. The pilots normally started the number 2 engine first; if they were to start the number 1 engine first, would the pressure readings have to be any different?

With the problem clarified, the maintenance crew decided to brainstorm regarding the possible solutions to the problem. The criticality of the issue was that the Department had sustained a complete hydraulic system failure on the same aircraft last year; the management was very concerned about an impending failure. Also, if this issue was not resolved, the Department would ground the aircraft and have to cancel its flights until the system read 2900 psi after the first engine start.

In the brainstorming process, the mechanics identified several different approaches, analyzed each approach, and developed a strategy. They decided that they would switch the gages between the two similar jets, search for any extraneous influences on the gage, and test the wiring more thoroughly. In the meantime, the chief of maintenance was to try to secure a letter of authorization from the manufacturer to operate the aircraft with 2800 psi pressure while the problem was being investigated. To relieve the pressure on maintenance, the chief pilot had already agreed to cancel the next day's flight, if necessary.

The extensive wiring checks and the extraneous influence checks did not identify any problems, but the swapped gage now read 50 psi higher than the original gage. So, the system pressure after the first engine start was 2850 psi and 2900 psi with both engines running. The chief of maintenance was able to get the authorization letter faxed-in from the manufacturer and get concurrence from the local Flight Standards District Office (FSDO). Therefore, the Company was able to release the aircraft on schedule.

Prior to the Error Reduction and Decision Making Process (incorporating concept alignment), this aircraft might have been rendered acceptable for continued operations by any individual's judgement call. The basis for this reasoning being that maintenance had tested the output pressure at the pump and found it to be within limits. Therefore, the problem was more likely to be with the instrumentation than the hydraulic system itself. Although the mutual understanding that has always existed among the pilots, mechanics and management would have prompted a quick meeting of all the groups, without the CAP, the corrective action and the return to service process would not have been carried as far. The CAP required the mechanics to continue to identify and rectify the root cause of the problem (follow steps 10(a) through 10 (c) and then back to Step 8 in figure 2). All of the participants seemed to be satisfied with the CAP approach because it maintained the focus on the solutions while desensitizing rank and authority of the people involved.

The following week, the FSDO rescinded the manufacturer's authorization because the manufacturer had authorized continued operation until the fault was identified. Now that the mechanics had identified the fault (as low relief valve setting and gauge error), the FSDO wanted the mechanics to repair the fault and then return the aircraft back to service. Until such repair, the pressure had to be 2900 psi after the first engine start or the aircraft did not meet dispatch criteria. The mechanics did not want to do any pressure adjustments until they received an approved adjustment procedure from the manufacturer. In the meantime, the flights were operated on schedule and no hydraulic system pressure problems reported. Subsequently, the mechanics received approved service data from the pump manufacturer and they adjusted the pump's pressure to return the aircraft to service under the authority of FAR Part 43.13 (a).

A QuantumPro debriefing, according to Robert Mudge, should lead to research into the reason for the 2900 psi restriction. The potential risk factors should be clearly understood and respected. Rather than being concerned with the current flight only, a broader view should be taken to improve future operations.

CASE 2: A CRACK IN FRAME 34 OF A FALCON 50 – The flight was received by a liaison mechanic and a cleaner. The cleaner opened the cargo door and discovered that the door support cable had broken He reported it to the liaison mechanic. The mechanic inspected the damage and noted the squawk in the discrepancy log of the aircraft.

The next morning, the maintenance crew inspected the damage in more detail and noted that there was about a 1.5 inch crack in Frame 34. They researched the Structural Repair Manual (SRM) for a repair scheme and found that the manufacturer had a repair kit available for that kind of damage. The repair kit had to be ordered from France. That meant that the kit would have to go through US Customs at the port of entry. Also, because of the upcoming three-day weekend, the kit would not get to them in time for the next flight. The maintenance crew decided to seek the manufacturer's authorization to operate the aircraft.

The local FSDO's Principal Maintenance Inspector (PMI) for the Department was on leave and so the chief of maintenance had to discuss the matter with another inspector at the FSDO. That morning, the FSDO supervisor was busy and so he directed the chief to an Avionics Inspector (Principal Airworthiness InspectorBPAI) who gladly volunteered. Based on the letter from Dassault Engineering to continue operations with conditions, the chief left the FSDO with an assurance that everything would be fine and the FSDO was going to provide their own approval soon. The inspector did not think that Dassault's letter was enough to meet the criteria specified under FAR Part 43.13 (a). So, at about 3:00 pm, he called the chief and informed him that he would not approve the continued operation of the aircraft even if the manufacturer approved it. Recognizing the gridlock, the chief's fall back position was to cancel the flight.

Subsequently, the flight crew, chief of maintenance, and the aviation department manager met on this issue. The manager suggested that the chief speak with the FSDO manager to seek a more precise clarification. So, the chief applied the CAP to seek a logical explanation regarding the matter. He called the PAI but was unable to reach him and so the chief left a voice mail message telling the PAI that he was going to contact the FSDO supervisor to clarify any misunderstanding. The chief tried to contact the supervisor, but got his voice mail as well. So he left a message that he would be contacting the FSDO manager to seek clarification of the issue. Upon contacting the manager, the chief requested that he (the manager) investigate the matter as a third-party and provide appropriate clarification. The FSDO manager discovered that the PAI had noted that Dassault Engineering had not specified the length of the crack that was acceptable for continued operations and therefore the PAI had ruled that the Dassault letter was unacceptable. However, none of the inspectors had actually seen the crack and so the FSDO supervisor volunteered to visit the corporate hangar and inspect the crack. Upon inspecting the crack, the FSDO supervisor found the Dassault letter acceptable and with the chief, co-approved aircraft operations per manufacturer's instructions. The Department was able to operate the aircraft the following week. Per the manufacturer's operational instructions, the crew monitored the crack and reported to maintenance after every landing. The crack had not grown. It was repaired in the following week.

The particular need for validation of concepts from a third party source is mainly due to the CAP process. The chief of maintenance had some difficulty communicating with the FSDO, but he used the CAP process to ask the FAA inspector for validation of his concept and was able to present his own argument validating his concept. Together, they were able to realign their concepts and resolve the issue professionally.

CASE 3: MAXIMUM DEMONSTRATED CROSSWIND COMPONENT – The flight crew had been using the CAP for over five years prior to this event; moreover, they had been trained in the entire QuantumPro management system. They are required to have a debriefing of each flight as soon after the flight as possible. In this case, the crew had just flown in from Fort Collins in a Astra Jet. The event that they chose to debrief had actually happened on their way in to Fort Collins. The aircraft was on the final approach and the copilot noticed that the prevailing crosswind was close to the maximum demonstrated crosswind component for that aircraft. Fortunately, the wind remained within the limits and no evasive action was necessary. However, upon returning to the base, the crew thought that the situation was worth discussing.

The maximum demonstrated crosswind component for the aircraft was 23 knots. The captain claimed that just because the maximum *demonstrated* crosswind component was 23 knots, doesn't mean that the aircraft cannot handle any more than that value. On the other hand, the co-pilot believed that maximum demonstrated crosswind component value was the Department's operational limitation and so anytime the wind velocity exceeded that value, he would seek an alternate airport or runway. He had heard the department manager say about four years ago that the manufacturer's published maximum demonstrated crosswind were the Department's limitations. In fact, he actually operated under this more conservative concept for four years! Consequently, if they had to have been in a very high crosswind situation and the co-pilot had been landing the airplane, he would have elected to go around and the captain would have been taken by surprise. This was clearly a misalignment of concepts. Nonetheless, if neither of the concepts can be validated by an independent third source, the concept alignment process calls for the crew to choose the most conservative concept. In this case, they should treat the demonstrated crosswind component as the absolute limit until clarification was obtained.

Upon further discussion between the two pilots, the co-pilot was not able to validate his concept in any documented format and so he requested the department manager to make the call. The manager validated the co-pilot's concept and the captain agreed. They concurred that there was a need for a more concrete Department policy that would clarify the operating limits for all and would still provide some latitude for pilot judgement based on his/her experience, the aircraft limitations, and environmental conditions. The chief pilot agreed to develop an operating policy.

CONCLUSIONS

The aviation department was able to incorporate CMR, Inc.'s human factors training in their maintenance as well as flight departments. More importantly, the training has facilitated the communication between the flight and the maintenance departments. Granted that with only four aircraft, eighteen pilots and nine mechanics, it is relatively convenient to implement the human factors training. However, it is also essential to recognize that the structure and process that was developed by the aviation department is so simple and straight-forward that all the mechanics and pilots understand it. Everyone in the Department agrees that there has been a definite behavior change as a direct result of the human factors training.

To the external observers, it was clear that for this approach to succeed in other organizations, the following prerequisites must be satisfied:

1. The management must have a clear and high-caliber personal standard of success which is aligned with the corporate mission and goals.
2. The strong positive attitude of the management must be expressed via complementary behavior, consistently.
3. In addition to the management, the organization will need a few key people from among the pilots and the mechanics who also have their personal standard of success aligned with the corporate mission and goals. These key employees (the concept leaders) along with the management will drive the CAP to greater detail (through steps 10(a), (b), and (c)). Incentive programs may be developed to encourage the concept leaders.

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